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Postero-inferior condylar movement induced by artificial occlusal interference on the balancing side during fictive mastication in rabbits

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ABSTRACT

Objective: Tooth contact does not occur on the balancing side during mastication. Hence, it is possible that the presence of occlusal interference on the balancing side causes mandibular rotation followed by atypical condylar movement because the jaw-closing muscle activity on the working side is greater than on the balancing side. The aim of the present study was to investigate the relationship between occlusal contact on the balancing side and condylar movement during mastication.
Methods: EMG activity of the masseter (MS), lateral pterygoid (LP) and digastric (DG) muscles and jaw movements were recorded. Condylar movements in the sagittal plane were recorded using a high speed charge-coupled device (CCD) camera. Incisal point movements were recorded using a magnet on the mentum and a magnetometric sensor on the nasal bone. A removable biting plate was used to introduce an artificial occlusal interference on the balancing side.
Results: Nine of the 10 rabbits showed large postero-inferior condylar movement (Pi-Cm) when a biting plate was applied on the balancing side. Five rabbits showed very small Pi-Cm when a biting plate was applied on the balancing side. In the small Pi-Cm group, MS activity decreased markedly and LP and DG transient activity appeared in the early occlusal phase in the presence of the biting plate.
Conclusion: Interference on the balancing side always caused Pi-Cm on the ipsilateral side during mastication. However, the degree of Pi-Cm was often decreased by a jaw opening reflex response.

1. Introduction

Temporomandibular disorder (TMD) involves symptoms including pain in the temporomandibular joint (TMJ) and/or masticatory muscles, restricted mandibular movement, and noise from the TMJ during jaw movement. Various factors, such as occlusal factors, trauma, parafunction, gender and stress are cited as possible causes of TMD (Dworkin et al., 1990; Koh & Robimson, 2004; Oral, Bal, Ebeoglu, & Dincer, 2009; Tanaka, Detamore, & Mercuri, 2008). Articular disk displacement is found frequently in patients with TMD (Buescher, 2007; Tanaka et al., 2008). Sustained and substantial stress imposed on the TMJ may induce elongation of the ligamental attachment of the disc to the condyle and deformation of the disc, (Nickel, Iwasaki, Beatty, Moss, & Marx, 2006) both characteristics of patients with TMJ disorder (Tanaka et al., 2008). Disruption in cooperation between the mandibular condyle and the articular disk during jaw movement may cause unusual condylar movement that may impose stress on the TMJ. Some research indicates that changes in occlusal contacts may affect the movement of the mandible (Huang, Whittle, Peck, & Murray, 2006; Karlsson, Cho, & Carlsson, 1992).

Because tooth–tooth contact does not occur on the balancing side during mastication, the mandible appears to be supported at three places during the masticatory power stroke (occlusal phase): the two joints and the portion along the working side teeth. The mandible is stable if the resultant vector of the jaw-closing muscle forces lies within the triangle of support. If it does not, one of the three contact points will be separated as the mandible rotates around a line connecting the other two points (Weijs & Dantuma, 1980) (Fig. 1A).

Morita et al. (2015) studied condylar movement in the presence of a metal biting plate during fictive mastication in rabbits. According to their report, when there was interference on the working side from a metal biting plate, although there was no apparent change in the EMG activity on the working side masseter muscle (MS), postero-inferior condylar movement (Pi-Cm) was

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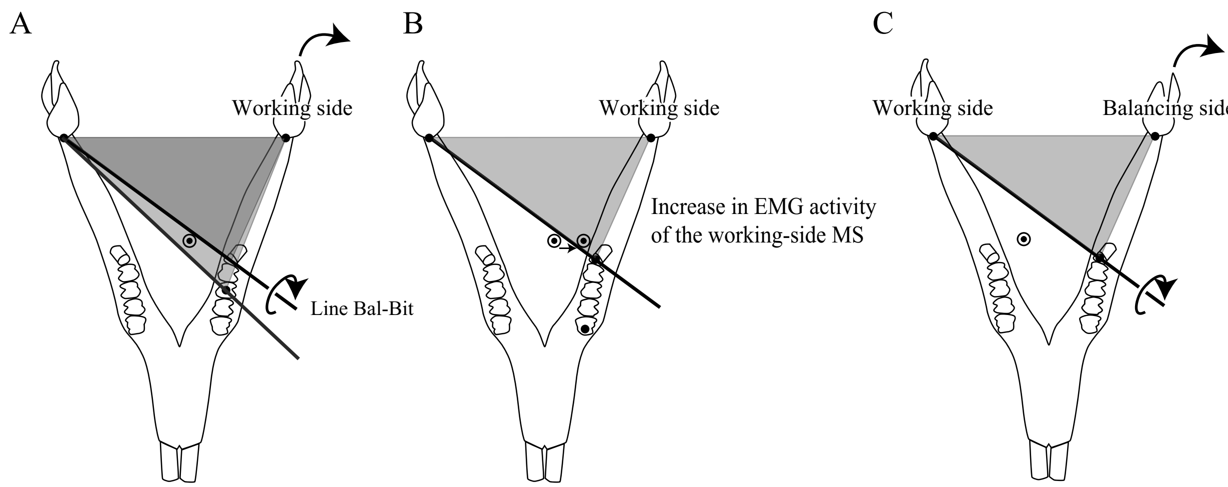

Fig. 1. Triangle of support of the mandible. (A) Horizontal view of the rabbit mandible superimposed with a triangle consisting of two joints and a biting point on the working side (the left side in this case). The resultant vector of all the jaw-closing muscle forces is supported at each corner of this triangle during the occlusal phase of mastication, if the resultant vector is within the triangle. However, the mandible could rotate around a line connecting the balancing side condylar point and the biting point along the occluding row of teeth (line Bal-Bit), when the resultant vector lies out of the triangle of support because the biting point is restricted to the most posterior tooth (M3). The curved arrow beside the working-side condyle indicates postero-inferior condylar movement due to this mandibular rotation. (B) The increase in muscle activity on the working side shifts the position of the resultant vector even further to the working side. (C) The mandible can rotate around a line connecting the working side (the right side in this case) condylar point and the biting point, when the resultant vector lies out of the triangle of support because there is a premature contact on the balancing side. Filled circles on the row of teeth indicate the biting point, and open circles with an inner dot indicate positions of the resultant vector at which the vector passes through the plate.

observed on the ipsilateral side during the occlusal phase in half of the rabbits. However, when working side MS activity increased markedly, Pi-Cm was not observed during the occlusal phase. Because a marked increase in MS activity on the working side shifts the resultant vector towards the working side, mandibular rotation was prevented (Fig. 1B). These results indirectly support the hypothetical model of the triangle of support of the mandible. We hypothesized that interference on the balancing side would always cause Pi-Cm on the ipsilateral side during mastication because the resultant vector is outside the triangle of support (Fig. 1C).

The aim of the present study was to test this hypothesis in fictive mastication induced by electrical stimulation of the cortical masticatory area (CMA) in anesthetized rabbits. For this purpose, a metal biting plate on the balancing side was used. We examined whether Pi-Cm on the ipsilateral side occurs, possibly due to inevitable mandibular rotation, under existing balancing side interference conditions.

2. Materials and methods

The surgical procedures were similar to those described and reviewed previously (Morita et al., 2008, 2015). Ten male rabbits (body weight, 2.4–3.7 kg) were injected intramuscularly with ketamine (Ketalar, 75 mg/kg, Sankyo, Japan). After tracheal cannulation, anesthesia was maintained with isoflurane (1% Forane, Abbot, USA) during surgery. Each animal's head was fixed to a stereotaxic apparatus according to the method used by Sawyer, Everett, and Green (1954) so that lambda was located 1.5 mm below bregma. To allow electrical stimulation of the cortical masticatory area (CMA), bone on the right side of the cranium was removed in the region 0–6 mm anterior to bregma and 1–8 mm lateral to the midline to expose the cortex.

To record the movement of the lower incisal point, a magnet and a magnetometric sensor were fixed to the mentum and the nasal bone respectively. To observe the movement of the mandibular condyle directly, the superior-posterior part of the left mandibular condyle was exposed. A marker with a printed + sign was attached to the bone surface of the exposed mandibular condyle. The central crossing point of the + sign was 3 mm inferior to the superior border of the mandibular condyle and 4 mm anterior to its posterior border. To record EMG activity from the MS on the left and right sides and the anterior belly of the digastric (DG) on the left side, two electrodes consisting of a ring (diameter: 2 mm) of silver wire (φ: 0.3 mm) connected to the tip of a teflon-coated stainless steel wire (φ: 0.25 mm) were sutured into the central portion of the superficial MS on both sides. To record EMG activity from the lateral pterygoid (LP) on the left side, wire electrodes (φ: 0.1 mm stainless steel wire insulated with resin except for the tip which was bent like a hook) were inserted from the inferior margin of the orbit. During the surgery, the rectal temperature was kept at 38.5–40 °C with a heating pad, and the rabbit was monitored continuously by electrocardiogram.

These surgical procedures were approved by the Aichi-Gakuin University School of Dentistry Intramural Animal Care and Use Committee.

2.1. Biting plate

The custom-made biting plate was almost the same as that described previously (Morita et al., 2015). A biting plate fabricated from aluminum was fixed to the occlusal surface of upper molar on the left side and around the upper central incisors. The biting plate was adjusted by grinding areas of occlusal interference with a dental drill so that the region of occlusal contact was as small as possible and occlusal contact was made at the most posterior end of the teeth. Following this procedure, the plate was less than 1.0 mm in thickness.

2.2. Electrical stimulation of the CMA

After completion of the surgical procedures, inhalation anesthesia with isoflurane was terminated, and anesthesia was maintained by injection of urethane (1000 mg/kg) into the auricular vein. For electrical stimulation of the CMA approximately 2 mm anterior to the bregma and approximately 6 mm lateral to the midline, tungsten electrodes (0.010″, 12 MΩ, A-M Systems, USA) were used. Repetitive electrical stimulation (0.3 ms duration,